B-6150
5/04

Irrigation of Forage Crops

Juan Enciso, Dana Porter, Guy Fipps and Paul Colaizzi*

Irrigation can increase the production of forages where rainfall is limited. In planning an irrigation system it is important for farmers to know how to determine the water requirements of the crops they are growing.

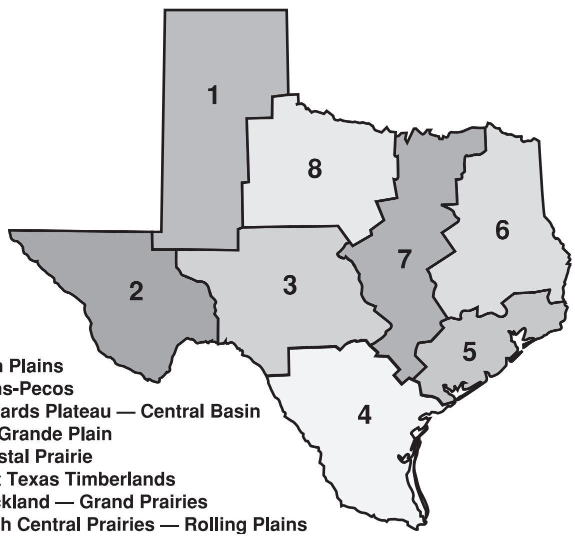

Figure 1. Land resources divisions and irrigated areas.
Source: Durwood, 1960. Texas Water Board of Engineers.

Geographic location, soil type, time of the season, and the way a crop responds to water all affect the amount of water a particular crop needs. Farmers should also know the characteristics of different irrigation systems.

Seasonal and Peak Water Requirements

Forage crops include:

- cool-season annuals (wheat, oats);
- warm-season annuals (corn, sorghum and hay grazers, which are crosses of sorghum, sorgo and sudan grasses); and
- perennials (alfalfa and grass pastures).

Table 1 shows seasonal and peak water requirements of common forage crops in the various regions of Texas. Water requirements vary during the growing season, as is shown in Figure 2. The peak water requirement is defined as the amount of water the plant needs each day during the month of the highest demand, which is usually July in Texas. Peak

Table 1. Water requirements for selected forage crops.

	Alfalfa and pastures		Sorghum		Corn	
Location	Seasonal (in.)	Daily (GPM/ac.)	Seasonal (in.)	Daily (GPM/ac.)	Seasonal (in.)	Daily (GPM/ac.)
1. High Plains	58-66	6.6	21-26	6.2	27-31	6.7
2. Trans-Pecos	65-67	6.7	27	6.6	31	8.5
3. Edwards Plateau – Central Basin	59-67	6.7	23-26	6.1	27-31	8.8
4. Rio Grande Plain	50-67	6.8	17-23	5.6	20-27	7.7
5. Coastal Prairie	47-49	4.7	18	4.8	21.5	6.5
6. East Texas Timberlands	46-49	4.9	19	4.7	21	5.7
7. Blackland – Grand Prairies	49-51	4.9	20	4.9	23	6.5
8. North Central Prairies – Rolling Plains	58-62	5.2	25	4.8	27-30	7.3

Durwood, M. R. M. Dixon and O. Dent. 1960. Bulletin 6019. “Consumptive use of water by major crops in Texas.” Texas Board of Water Engineers.

* Respectively, Assistant Professors and Extension Agricultural Engineers, The Texas A&M System; Professor and Extension Agricultural Engineer, The Texas A&M System; and Agricultural Engineer, USDA-ARS.

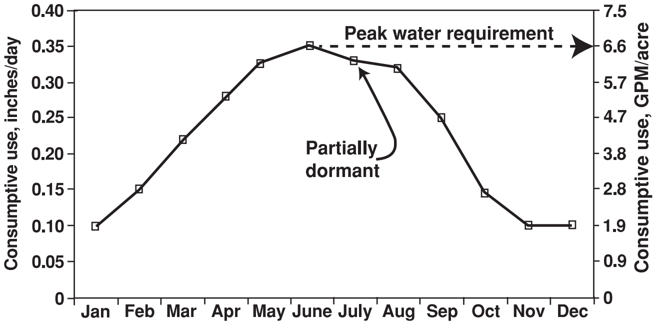

Figure 2. Alfalfa peak and seasonal water requirements.
Source: Pair, et al. 1983. Irrigation.

water requirements help determine how many acres can be irrigated with a particular canal or well capacity. The peak water requirement is generally expressed in gallons per minute required per acre, or the inches required per day.

Example 1. How many acres of fully irrigated alfalfa can be supported with a well yielding 800 GPM if the alfalfa has a peak daily demand of 6.6 GPM per acre in the High Plains?

$$\text{acres} = \frac{800 \text{ GPM}}{6.6 \text{ GPM/acre}} = 121 \text{ acres}$$

Forage Yield and Water Used

Forage yield is influenced by the amount of water the crop receives and by the length of the growing season. In some areas of Texas the growing season allows six to seven cuttings of alfalfa. Alfalfa needs 5 to 6 inches of water to produce 1 ton per acre. With irrigation it may be possible to obtain 12 tons per acre of alfalfa in some years.

Water use efficiency is the crop yield per unit of water applied. The more water applied to a crop, the lower the water use efficiency because some water will be lost through runoff or deep percolation into the soil. The type of irrigation system used and its management greatly influence water use efficiency.

Studies in the High Plains have shown that forage sorghum, grain sorghum, and hay grazers can produce 1.1 tons of fresh matter per inch of water applied (including rainfall and irrigation), when the silage contains 65 percent moisture at harvest.

Irrigation Methods

Irrigation water can be applied by sprinkler, surface and subsurface drip irrigation systems. Each method has advantages and disadvantages. Water is distributed through these systems by gravity flow (as in surface irrigation) or by pressurized flow (as in sprinkler irrigation and subsurface drip irrigation).

Sprinkler Systems

When sprinklers are properly designed and managed so that the amount of water applied does not exceed the amount the soil can hold, runoff and water logging problems can be avoided. A disadvantage of all sprinklers is the foliar damage that can occur in some crops (including alfalfa) if the water has a high concentration of salt. Sodium ($Na+$) or chloride ($Cl-$) concentrations greater than 350 ppm may cause this problem. Irrigation must be managed more carefully if the salt concentration is high.

Sprinklers can be classified as permanent, portable, and continuous movement.

Permanent sprinklers

Permanent sprinklers are used on small plots of less than 10 acres. They might also be used where labor costs need to be reduced, on small ranchettes with pastures for horses, or in areas where household waste water is being reused.

Portable sprinklers

The portable systems are either laterals that can be moved manually or mechanically or single big sprinklers commonly called big guns.

Systems with **hand-moved laterals** are assembled from pipe sections of aluminum tubing connected by quick couplings. Each pipe has a riser pipe supporting a sprinkler head. The application rate depends on the sprinkler size and spacing. The mainline is usually buried in the soil and the laterals take the water from a riser with a hydrant valve (Fig. 3, left). The change of sprinkler position is facilitated by quick coupling pipe sections at the end of the pipe (Fig. 3, right). Pipe sections

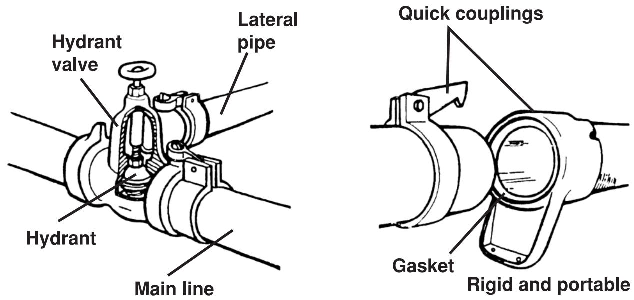

Figure 3. Hydrant valves (left) and quick coupling aluminum pipe (right).
Source: Soil Conservation Service. 1971.

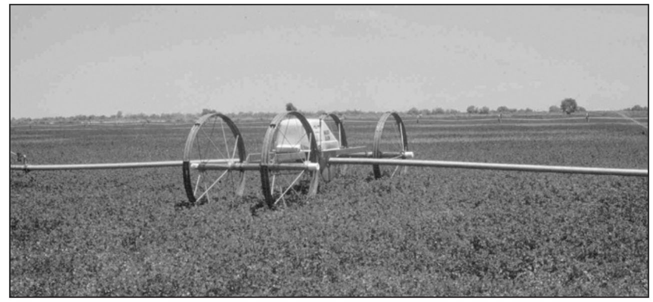

Figure 5. Side-roll sprinkler system.

usually are 30 or 40 feet long and 2, 3 and 4 inches in diameter. The pressure in the pipe is usually 75 psi. Irrigation times are 12 to 24 hours. Hand-moved sprinkler sets are moved manually from one irrigation position to another as illustrated in Figure 4.

Mechanically moved sprinklers include side-roll and power-roll systems (Fig. 5). The main lines are usually buried and have hydrants in strategic points to connect the laterals (as in Fig. 4). The system remains connected in one position for some time. After irrigation is completed in this position, the line is unhooked and moved to the next position. Typical systems are up to 1/4 mile (1,320 feet) long and they are moved every 60 feet, so an area of 1.8 acres is irrigated in one set time. One of the problems with these systems is that a lot of labor is required to change positions and to keep them aligned.

Hand-moved big guns are sprinklers with large diameter nozzles (5/8 inch or more) that discharge at least 100 GPM. These sprinklers are rotated with a rocker arm drive and can irrigate an arc. Because they operate under high pressure (generally more than 80 psi), the energy requirements and operating costs are relatively high. That makes them best suited for supplemental irrigation. A single big gun sprinkler and a common change of irrigation positions are shown in Figure 6. This is one of the least efficient kinds of sprinkler systems.

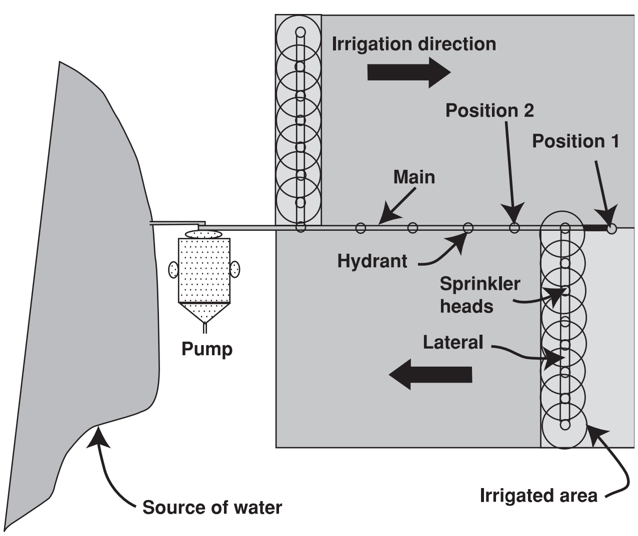

Figure 4. Movement of a hand-moved lateral system from one position to another.

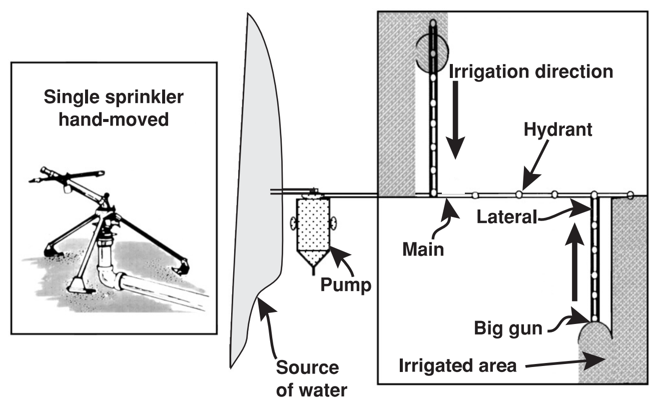

Figure 6. Big gun (left) and changing positions with two big gun sprinklers (right).
Source: Soil Conservation Service, 1971.

Continuous movement sprinklers

The continuous movement systems are the center pivots (Fig. 7), linear systems (Fig. 8) and traveler big guns (Fig. 9).

Center pivot irrigation systems are generally preferred over other sprinkler systems because of their low labor and maintenance requirements and easy operation. Center pivots sprinkle water from a continuously moving overhead pipeline that is supported by towers. The towers are driven by electric or oil hydraulic motors located at each end tower; these are controlled by a central panel (Fig. 7). The typical distance between towers is 90 to 250 feet. The most common overall length of a pivot system is 1,320 feet (1/4 mile); this is about the radius of the circular area of approximately 126 acres, often inscribed within a square section of 160 acres. A system this size usually has 6-inch diameter laterals (for a capacity of up to 900 GPM). Pivots can be 2,640 feet long (1/2 mile) and cover a circular area of 503 acres. These half-mile pivots are inscribed in a 640-acre square (1 section, or 1 square mile of land) and usually require 10-inch pipe laterals. Some smaller systems are now available for smaller fields. While full-scale systems can be shortened, the unit cost (cost per acre) of cut-down systems is often higher. Corners of square areas can be irrigated with a special corner apparatus attached to the pivot. Most pivots are permanently installed in the field. However, some "towable systems" can be moved between fields. Properly designed and maintained center pivots have very uniform water distribution (more than 90 percent), making them well suited for fertigation and chemigation.

Figure 7. Center pivot sprinkler system.

Linear moving lateral systems can be self-propelled with diesel motors and directed by guidance systems. These systems are used to irrigate rectangular fields with uniform topography. The distribution uniformity of these systems can be very high (more than 95 percent). Linear systems can take the water from an open channel or from a hydrant with a flexible hose (Fig. 8).

Figure 8. Linear moving system with a flexible hose.
Source: Texas A&M University Research and Extension Center at Weslaco.

Figure 9. Traveler big gun irrigation system.
Source: Mexican Institute of Water Technology.

Center pivot and linear moving sprinkler systems can be equipped for MESA (mid-elevation spray application), LESA (low elevation spray application), or LEPA (low energy precision application). LEPA systems are more expensive initially because nozzle spacing is much closer. However, energy costs are lower and water application efficiency is high with LEPA systems. A variety of spray nozzles (with different spray patterns, delivery rates, etc.), drop hoses and drag hoses (for LEPA application) are available to accommodate different crops, cropping systems, and water management strategies. The MESA system requires 6 to 30 psi, while LESA and LEPA systems can work with 10 to 15 psi. Pressure regulators can make distribution more uniform on fields with sloping or undulating topography. Water application rates are adjusted by changing the speed of travel of the overhead lateral, which makes these systems adaptable to the permeability of the soil and the water needs of the crop. They are suited to many topographic conditions and soils.

A **traveler big gun** is a high-capacity sprinkler mounted on a self-propelled vehicle or on a vehicle dragged by the hose as it winds up in a reel (Fig. 9). The self-propelled type pulls itself along by winding in a cable as it drags the hose. The cable is anchored at one end. The hose-drawn traveler has a hose reel at the water supply end; a pump supplies the water to the gun and gives the hydraulic energy to the reel to pull it. Both types irrigate a semi-circular area. They do not wet the towpaths in which they are moving, but irrigate a strip of the field as they move along the towpath. As with portable big guns, they have relatively high energy requirements, have low efficiency, and are generally used for supplemental irrigation.

Surface Irrigation

Surface irrigation systems are suited to deep soils (more than 4 feet deep) of clay to loam texture. Surface irrigation efficiency can be improved by using either gated pipe or concrete delivery channels. This also reduces weed problems on field borders. The soil should have good water storage capacity because of the relatively long interval between irrigations. The most common surface irrigation systems are 1) sloping or graded furrows and borders and 2) level basins.

Sloping furrows and borders

Furrows are used to irrigate row crops such as corn, vegetables, cotton and sorghum, while borders are used to irrigate cover crops such as pastures and alfalfa. With sloping furrows and borders, it is important to balance the speed of water advance and inflow to apply the desired depth of water uniformly. If water advances too quickly there will be excessive runoff or deep percolation at the downstream end. If water advances too slowly there will be too much deep percolation at the upstream end. Deep percolation losses can be managed by irrigating alternate furrows, compacting furrows with tractor wheels before irrigating, or using surge irrigation. Runoff loses can be reduced by using runoff recovery systems, shorter furrow lengths, and dams at the lower ends of furrows. The components of a sloping border irrigation system are shown in Figure 10.

Level basin irrigation and level furrows

The development of laser-controlled grading in the1970s promoted the adoption of level basin irrigation. The objective of level basin irrigation is to deliver a uniform depth of water to a level field by flooding it very quickly. The size of the basin and the infiltration rate of the soil determine the flow rate. Usually 3 to 5 inches of water are applied, depending on the soil conditions. A basin must be properly designed and leveled so that it applies water efficiently and uniformly (Fig. 11).

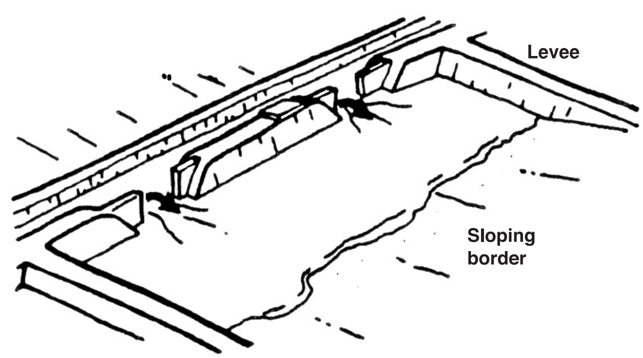

Figure 10. A sloping border irrigation system.

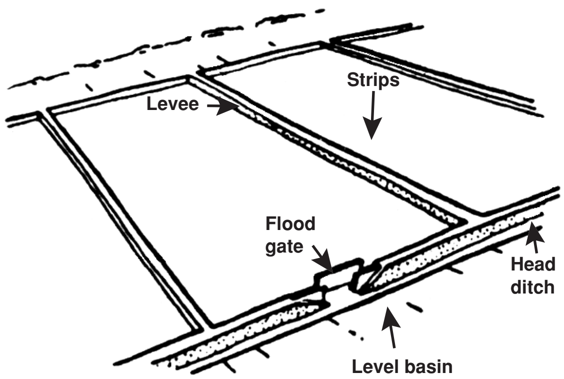

Figure 11. A level basin system.
Source: Soil Conservation Service. 1971.

Figure 12. Installation of a subsurface drip irrigation system.

Subsurface Drip Irrigation

Subsurface drip irrigation (SDI) applies water through buried drip tapes spaced uniformly so that a uniform amount of water is applied between the drip lines. The spacing between drip tapes and the depth at which they are buried are important factors in system design. Soil texture, cultural practices, crops and economics will affect the spacing between drip lines. Sandy soils usually require a closer spacing than clay soils. Good results have been observed in pastures, hay and forage crops when lines are spaced 30 inches apart in sandy soils and 40 to 80 inches apart in medium-texture soils. Tapes are usually buried 13 to 20 inches deep for forage crops. One of the advantages of SDI is that irrigation can continue during hay cutting and bailing, which often increases productivity and quality. In fact, studies have shown that crop production can be higher with subsurface irrigation than with sprinkler irrigation.

SDI drip tapes can be clogged by soil or roots and damaged by gophers. Clogging usually can be prevented with proper filtration, maintenance, and mixing of fertilizers (if they are applied with irrigation water). To prevent roots from clogging the tapes, a chemical barrier can be created with the herbicides treflan or trifluralin. Figure 12 shows equipment used for the installation of an SDI system.

Selecting an Irrigation System

One way to measure the performance of an irrigation system is to calculate its irrigation efficiency. The irrigation efficiency is the volume of water stored in the root zone compared to the volume delivered by the system. The efficiency must account for deep percolation, evaporation and wind drift, and is highly affected by the uniformity with which the water is applied over the field. Selecting the right system and managing it well are the keys to good water use efficiency. When selecting a system, consider economics, site characteristics (soil, topography, water supply, etc.), crop requirements, and the overall farm operation. Table 2 lists various factors that affect the selection of an irrigation system, such as field slope, soil texture (infiltration and water-holding capacity), and cost.

To select the right system, analyze several options. For example, compare the cost of land grading for a surface system to the cost of installing a pressurized irrigation system. If the soil is shallow, some soil cuts during land leveling can diminish production. Another example is to consider whether the intake rate (rate of infiltration into the soil) for a surface system is so low that it will take several days to irrigate from one side of the field to the other. If so, there could be substantial water stress in the crop and a sprinkler system might be more efficient.

Summary

Remember that water requirements vary according to the location and time of the growing season, and that yields are affected by the amount of water applied. The irrigation system selected will influence the productivity per unit of water applied. Irrigation should be carefully managed along with other agronomic practices such as pest management and fertilization.

Table 2. Factors considered in selecting an irrigation system.

Factors	Sprinkler systems					Surface (gravity) irrigation systems			Drip
	Portable	Wheel roll	Solid set	Center pivot linear move	Gun	Graded border	Level border	Furrow	
Slope limitations:									
Direction of irrigation	20%	15%	None	15%	15%	0.5-4%	Level	3%	None
Cross slope	20%	15%	None	15%	15%	0.2%	0.2%	10%	None
Soil limitations: Intake rate (inches/hour)									
Minimum	0.1	0.1	0.05	0.3	0.3	0.3	0.1	0.1	0.02
Maximum	None	None	None	None	None	6.0	6.0	3.0	None
Texture	Medium to sandy	Medium to sandy	Medium to sandy	Fine to sandy	Medium to sandy	Fine to medium	Fine to medium	Fine to medium	Medium to sandy
Holding capacity (inches/feet)	3.0	3.0	None	2.0	2.0	2.0	2.0	2.0	None
Soil depth	None	None	None	None	None	Deep	Deep	Deep	None
Water limitations:									
Total Dissolved Solids (TDS)	Severe	Severe	Severe	Severe	Severe	Slight	Slight	Moderate	Slight
Rate of flow	Low	Low	Low	High	High	Moderate	Moderate	Moderate	Low
Climatic factors:									
Wind affected	Yes	Yes	Yes	Yes	Yes	No	No	No	No
System costs (2001 data):*									
Capital cost ($/acre)	400-500	400-500	450-800	400-600	350-400	500-600	650-1000	500-600	800-1200
Labor cost ($/acre)	>70	50	50	<10	>70	>70	50	>70	<10
Irrigation efficiency*									
	70-75	70-75	55-70	74-81	62-63	65-82	75-80	50-70	>90
Energy requirements (feet)									
Head required (feet)	140	140	140	45	185	5	5	5	45

*The efficiency values for sprinkler and subsurface drip irrigation systems were reported by Cuenca, 1989. The irrigation efficiencies were reported by Clemmens, 2000.

Source: Irrigation Water Use in the Central Valley of California. 1987. Division of Agriculture and Natural Resources, University of California. Department of Water Resources, State of California.

Additional Information

"Center Pivot Irrigation." B-6096, Texas AgriLife Extension Service.

Cuenca, Richard. 1989. Irrigation System Design: An Engineering Approach. Prentice Hall.

Clemmens, A. J. 2000. Level Basin Irrigation Systems: Adoption, practices, and the resulting performance. 4th Decennial National Irrigation Symposium, Phoenix, Arizona.

Durwood, M., R. M. Dixon and O. F. Dent.1960. Consumptive use of water by major crops in Texas. Bulletin 6019, Texas Board of Engineers.

Irrigation Water Use in the Central Valley of California. 1987. Division of Agriculture and Natural Resources, University of California. Department of Water Resources, State of California.

Pair, C. H., W. Hinz, K. R. Frost, R. E. Sneed and T. J. Schilts. 1983. Irrigation. 5th edition. The Irrigation Association.

Soil Conservation Service. 1971. Planning for an irrigation system. Ed. AAVIM.

Produced by AgriLife Communications, The Texas A&M System

Extension publications can be found on the Web at: http://agrilifebookstore.org

Visit the Texas AgriLife Extension Service at: http://agrilifeextension.tamu.edu

Issued in furtherance of Cooperative Extension Work in Agriculture and Home Economics, Acts of Congress of May 8, 1914, as amended, and June 30, 1914, in cooperation with the United States Department of Agriculture. Edward G. Smith, Director, Texas AgriLife Extension Service, The Texas A&M System.

500, New